July 2012 Technical Series 12-102

Design and Construction of the Northern Sustainable House E/9 Project – Dawson City, Yukon

INTRODUCTION

The harsh climate, limited transportation infrastructure, difficult permafrost conditions, high cost of building and operating housing and unique social and economic conditions present many challenges to the delivery of sustainable housing in the North. Additionally, many house designs used in the North do not reflect the culture and lifestyle of northern, and in particular, First Nations occupants.

To assist in addressing these issues, Canada Mortgage and Housing Corporation (CMHC) supported a northern housing provider, the Tr'ondek Hwech'in Han First Nation, in an exploration of the opportunities to improve the performance of northern housing. The project, known as the Northern Sustainable House (NSH) initiative, included consultations with northern housing providers and occupants to identify challenges, needs and potential design solutions. The project then proceeded to the design, construction and performance monitoring of a NSH model house (known as the E/2 house) that targeted energy consumption 50% less than had the house been constructed to the requirements of the 1997 Model National Energy Code for Houses (MNECH). From this first project, many lessons were learned about the challenges and opportunities in the design of sustainable housing in the North.

To take advantage of this new knowledge, the Tr'ondek Hwech'in Han First Nation quickly moved to design and construct a second duplex house (known, and referred to herein, as the E/9 project) that targeted energy consumption 89% below the energy consumption had the house been constructed to the 1997 MNECH. This Research Highlight provides an overview of the design and construction of the "Solar" and "Flex" duplex units of the E/9 project (Figure 1).

Figure 1 Northern Sustainable House E/9 Project ("Solar" unit left, "Flex" unit right)

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METHODOLOGY

A project design consultation team was established and, as a first step, the lessons learned from the E/2 project were reviewed. Based on the review, proposals for improved construction and insulation systems were developed and alternative space heating systems were evaluated. To achieve the greatest energy efficiency with a limited capital investment, the design team chose to first optimize energy consumption reduction and energy efficiency features, such as passive solar orientation, high insulation levels and airtight construction, energy efficient lighting and appliances and then consider renewable energy opportunities such as solar thermal and photovoltaics to further reduce household purchased energy requirements. Extensive energy modeling using Natural Resources Canada's HOT2000 residential energy simulation program and the RETSCREEN renewable energy analysis software was undertaken to determine whether the various design options considered would meet the 89% energy reduction target. Additionally, the costs, savings and other benefits of each option were also considered.

Four design options were modeled to optimize the energy efficiency of the E/9 project (Table 1). Option A estimates the energy consumption of the Flex unit with a structural insulated panel (SIP) wall and increased attic insulation. Option B estimates the energy consumption of the Solar unit with the same construction, supplemented with 6 m^2 of solar hot water panels. Option C estimates the energy consumption of the Option B Solar house, supplemented with 6 m^2 of photovoltaic panels. Option D estimates the net energy consumption of the Solar house with the addition of 80 m^2 of photovoltaic panels on a redesigned 45 degree sloped roof facing South.

Options A-D include a highly-insulated building enclosure, airtight construction with 0.75 ACH @ 50 Pa, triple-glazed low-E argon-filled windows and electric baseboard space heating, primary solar hot water heating (except in Option A) and heat recovery ventilation. The estimated total energy consumed in each option is compared with the estimated energy consumption of the original E/2 project and the baseline MNECH house. For each option, the housing

Table 1 Summary of Modelled Energy Consumption and Savings for E/9 House Energy Efficiency Options

Option	Description	Consumption (MJ/yr)[1]	Electricity kWh/yr	Electricity Cost $/yr[1,2]	Oil L/yr	Oil Cost $/yr[3]	Energy per area (kWh/yr/m^2)	Energy per area (MJ/yr/m^2)	Energy Saved (MJ/yr/m^2)	Energy % (of base)[4]	Energy Saved ($/yr)[4]	EGH #
A	E/9 'Flex' house	63,295	17,582	2,071	0	0	146	527	842	33	3,438	84
B	E/9 Solar house (with SDHW)	60,928	16,924	2,028	0	0	122	439	931	32	3,481	86
C	E/9 Solar house (with SDHW + PV)	58,146	16,152	1,935	0	0	116	409	951	30	3,555	87
D	E/9 'Target' (with Solar DHW + PV)	21,128	5,869	900	0	0	42	152	1218	11	4,609	90

[1] Lights + Appliances + Heat + Hot water
[2] Electricity cost based on Dawson 2006, $11.91 monthly, 1st 1,000 kWh @ $0.093, balance @ $0.1403. Excess electricity sold to the grid (for Target house only) @ lowest rate- $0.093/kWh.
[3] Oil cost based on Dawson 2006, $1.04/litre.
[4] The 'base' is the energy consumed by each E/9 house had it been constructed to the 1997 MNECH.

provider estimated the incremental costs to determine whether or not the options were financially viable.

Apart from the energy efficiency objectives, the design of the house had to be appropriate for the lifestyle and cultural needs of the First Nations occupants. The house also had to be easily built by regular construction trades people during the short building season in central Yukon. Ultimately, the E/9 project had to be economically viable for both the housing provider and the future occupants.

Once the selected design of the E/9 house was finalized, materials were ordered and construction began. The construction process was documented to better understand the implementation considerations associated with the design features included in the house.

FINDINGS

Design Features

The design exercise was completed with the preparation of construction drawings for a duplex consisting of one 139 m^2 "Solar" unit and one 121 m^2 "Flex" unit (Figure 2). The Solar unit has three bedrooms and primary solar hot water heating supplemented by secondary electric hot water. The Flex unit has two bedrooms and conventional electric hot water heating, and incorporates a FlexHousing™ feature that enables a third bedroom (now a covered porch area) to be easily added to the house in the future.

Both dwellings have high levels of insulation and air-tightness and use electric baseboards for space heating. Heat Recovery Ventilators (HRVs) in each unit provide continuous energy efficient indoor-outdoor air exchange.

Figure 2 Floor plan of the E/9 Solar and Flex Houses (Left - Solar unit, Right - Flex unit)

Electric baseboards were selected for space heating because this would avoid the problem of finding a small enough boiler and the control problems experienced with the fuel-fired hydronic system used in the original E/2 project. Electric baseboard heating also costs less to supply, install and maintain. Although electricity can be an expensive heating option, the very low estimated space heating energy requirements of the E/9 units are expected to result in affordable heating costs.

The E/9 design has the following energy-reducing features:

- Passive solar design: The building is oriented with its longer face towards the South. Large windows on the South and smaller ones on the East and West admit passive solar energy and natural lighting into the living and dining areas. Small windows on the North admit light to the bedroom, while reducing heat loss.
- Highly insulated building envelope: RSI 7 (R40) floor, RSI 8.4 (R47.5) exterior walls using structural insulation panels plus additional insulation added to the interior of the walls, RSI 14 (R80) raised heel truss roof, triple-glazed, low-E windows and airtight construction (target: 0.75 ACH @ 50 Pa).
- Heat recovery ventilation: Provides efficient and effective continuous indoor-outdoor air exchange to supply fresh air while venting moisture, stale air and odours.
- Solar hot water heating system in the Solar unit to offset the energy used for domestic hot water.

Cultural/lifestyle and FlexHousing™ features include:

- Accessibility: Vestibules, kitchens and bathrooms have 1,500 mm (5'-0") clear width, light switches are 1,100 mm above the floor, and exterior decks are flush with the main floor to accommodate occupants in walkers and wheelchairs. Site grading can be easily modified to include wheelchair accessible ramps to the entry vestibules.

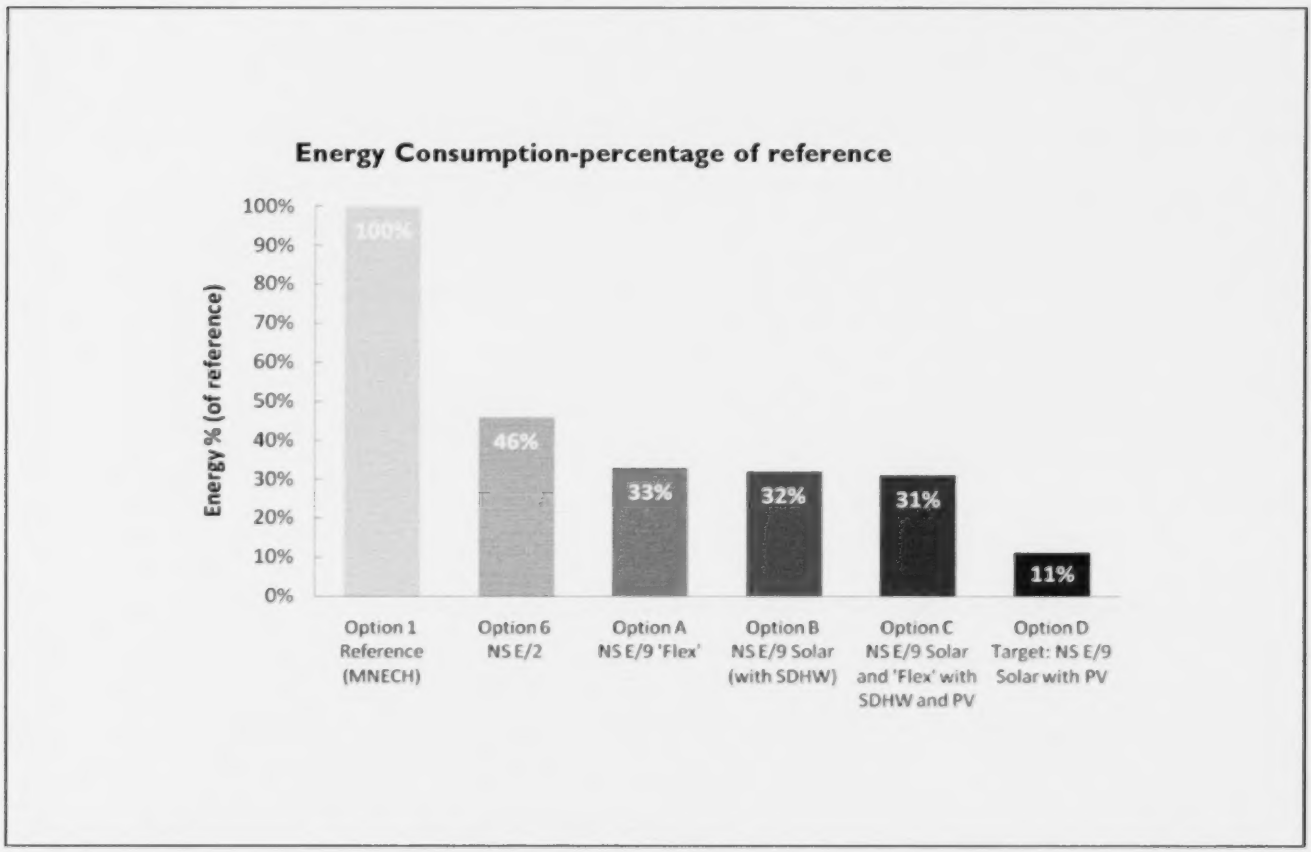

Figure 3 Energy Consumption of E/9 Options Relative to MNECH reference house

- Large vestibule with air lock: Contains storage for clothing, room for occupants with limited mobility and space for a bench.
- Open space: The living, dining and kitchen areas occupy a large, open space with abundant windows, which can accommodate large social gatherings and a variety of furniture layouts.
- Flex space: The covered deck of the Flex house has an insulated floor and ceiling making it easy to convert to interior space to address changing household needs over time.
- The houses are on one level and as close as possible to the ground, in keeping with the First Nations people's preference for ground-oriented dwellings that reflect their desire to live on the land.

Energy Modeling of Design Options for E/9 Houses

The design team determined that to reach the targeted 89% reduction, additional renewable energy systems (photovoltaic and solar hot water) would have to be added (Option D). However, the budget available for incremental costs was not sufficient to cover the Option D renewable energy systems. Therefore, it was decided that the E/9 units would be constructed according to options A and B to achieve an estimated 67 – 68% reduction in net energy consumption. If the energy savings of the Solar house prove to be sufficient, the Flex house could be converted to include solar hot water at a later date at a modest cost and with minimal disruption to the occupants.

Costs and Benefits

The incremental costs of the energy-saving features selected for the Solar unit were estimated at $52,042 and in the Flex unit at $33,292 over the MNECH reference house. The energy saving features in the Flex house would add $2,300 per year to the costs of a 25 year mortgage. However, given the estimated $3,400 annual energy savings, the homeowner could save up to $1,100 per year. The incremental cost of the energy-saving features in the Solar unit equates to $3,600 in additional costs per year of a 25 year mortgage. The expected $3,500 annual energy savings would almost offset the additional mortgage costs. The savings improve with any increase in energy costs.

CONCLUSIONS

The E/9 project demonstrated the full extent to which the energy performance of a northern house could be optimized within a limited budget while also addressing the cultural and lifestyle needs of the First Nations occupants. Although the original energy savings objective could not be met with the financial resources available, the highly insulated walls, triple glazed windows, passive solar orientation and airtight construction are expected to reduce the energy consumption by almost 70%, at a cost that can be offset by energy savings. The E/9 units represent an optimal design for the Tr'ondek Hwech'in Han First Nation with respect to the maximum energy efficiency that can be achieved without resorting to extensive, and expensive, renewable energy systems. Renewable energy production could offset some of the household energy needs in order to meet the 90% reduction target but only at a significantly higher cost. Another key conclusion was that the capital cost savings associated with the installation of relatively inexpensive electric baseboards allowed the construction budget to include solar hot water heating and increased building envelope insulation.

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Housing Research at CMHC

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Printed in Canada
Produced by CMHC 11-07-12

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